Space Weather Technical Forecast

Issued on Monday, 03 October 2022 at 01:30 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: G1/G2 Minor-Moderate storms Day 1 and Day 2. Ongoing likelihood of M-class flares with chance of X-class flares due to AR3110 and AR3112.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been Strong over the last 24 hours, with an X1.0 at 02/2015 UTC, and an M8.3 flare observed at 02/0220 UTC, both from AR3110 Dsc/Beta-delta in the northwest. This is a small but unstable and complex region, with north-south aligned field and ongoing penumbral growth along its northern spots. Low M-flares were also observed from AR3112 Fkc/Beta-gamma-delta, a longitudinally wide spot in the northeast disc. This appears comprised of a string of umbral and penumbral regions, with a larger more compact intermediate region with ongoing development. There are eight sunspot regions on the disc, with five numbered, including AR3112 and AR3110, and three further newly developing regions. A further feature of note is a large southern hemisphere filament which will require monitoring for any potential lift, along with a number of other filaments also on the Earth-facing disc.

In the last 24 hours, two potentially Earth-directed CMEs have been observed leaving the Sun, due to the M8.3 and X1.0 flares. The latter has yet to be analysed, with the former likely missing but with a chance of a glancing arrival on the 4th. These CMEs may combine with those already en-route that were observed leaving the Sun on the 1st.

Solar Wind / Geomagnetic Activity: Solar wind parameters at L1, as measured by ACE, have shown the arrival of the fast wind of CH28/+. Wind speeds have risen from around 400km/s to be elevated at 550-600 km/s, although density was largely below average. The total IMF, Bt, was mostly weak at 5-8nT, but climbed to moderate levels of 6-9nT at 02/2000 UTC, likely in response to the fast wind onset. The north-south component, Bz, varied weakly between +6nT and -5 nT at first, but become moderately negative from 02/2000 UTC at -8 to -4nT. The phi angle was positive (away from the Sun). The resultant geomagnetic activity was mainly Quiet to Unsettled (Kp 0-3), but rose to G1/Minor Storm (Kp5) at 03/2100-0000.

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10 MeV) as measured at GOES16, is currently just above normal background levels, but well below the S1/Minor Storm threshold having slightly increased in response to the X1.0 flare of AR3110. High energy electron flux (greater than 2 MeV) was at background levels. The associated 24-hour fluence remained well below the Active (1e8 integrated pfu) threshold. Observed fluence at 03/0000UTC was 1.28e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Solar activity is forecast to be Moderate to High, with further M-flares or perhaps X-flares possible from AR3110 and AR3112.

Solar Wind / Geomagnetic Activity: There are potentially four CME's in which could influence Earth. The most notable was from a filament eruption to the east of AR3113 around 01/1200 UTC, and will potentially arrive late on day 1 (3rd) or early day 2 (4th), although this low confidence with a glancing impacts possible. Further CMEs from the M and X-flaring of AR3110 on the 1st and 2nd

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follow, however these are lower confidence for arrival, but may combine with the first arrival to give further enhancement through day 2 (4th). The uncertainty around these CMEs gives very low confidence in the forecast. Otherwise current fast winds are expected to only gradually ease day 3 and day 4, becoming slightly elevated by the end of the period. Geomagnetic activity is forecast to be mainly Unsettled to Active day 1 (3rd) with G1-G2 Minor to Moderate Storms possible at first, and then a further chance of G1-G2 (Minor to Moderate storms) either late day 1 or early day 2 (3rd-4th) with any CME arrival, perhaps ongoing into day 3 (5th) with any CME arrival. Otherwise, a general trend back towards Quiet, with isolated Unsettled intervals is expected later day 3 and day 4 (5th-6th).

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10MeV) is expected to be near background for much of the period, but with further small enhancements likely, and slight chance of rising above the S1 level through the period due to any further M or X-flares that occur, mainly from AR3110 but perhaps also AR3112. The high energy (greater than 2MeV) electron flux has been at background levels, and is likely to rise due to the recent fast wind arrival. In the absence of any CMEs, this would occur later day 1 and through the rest of the period, with an increasing chance of flux becoming persistently High. However, this is uncertain due to the potential CME impacts, with any rise likely occurring once their influence subsides. The associated 24 hour fluence will likely stay below the Active threshold until at least day 3 or day 4 (5th or 6th), but with an increasing chance of rising above.

Figure 1b. Observed Solar winds

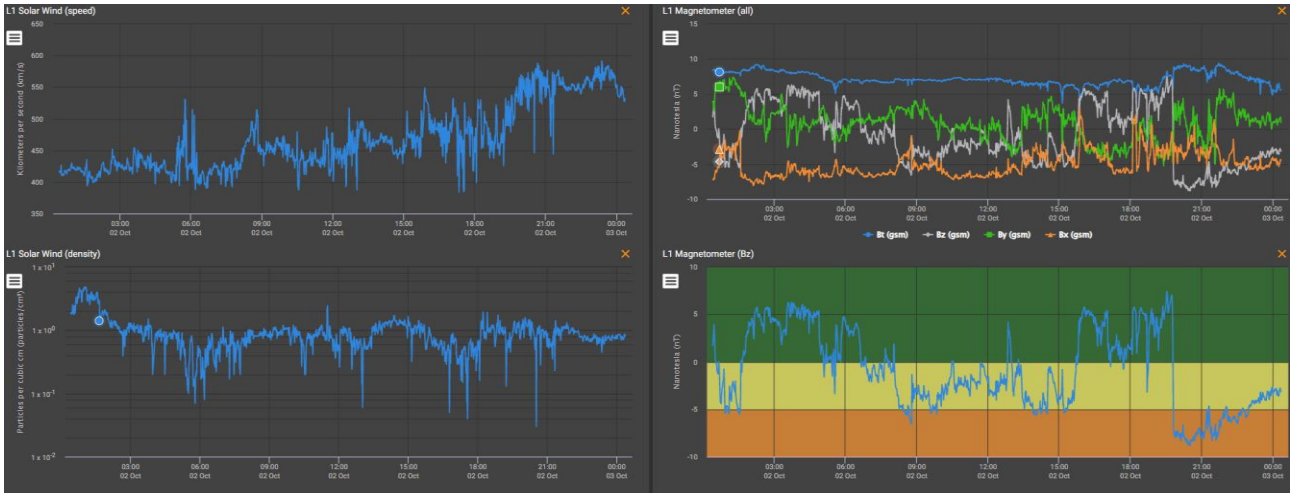

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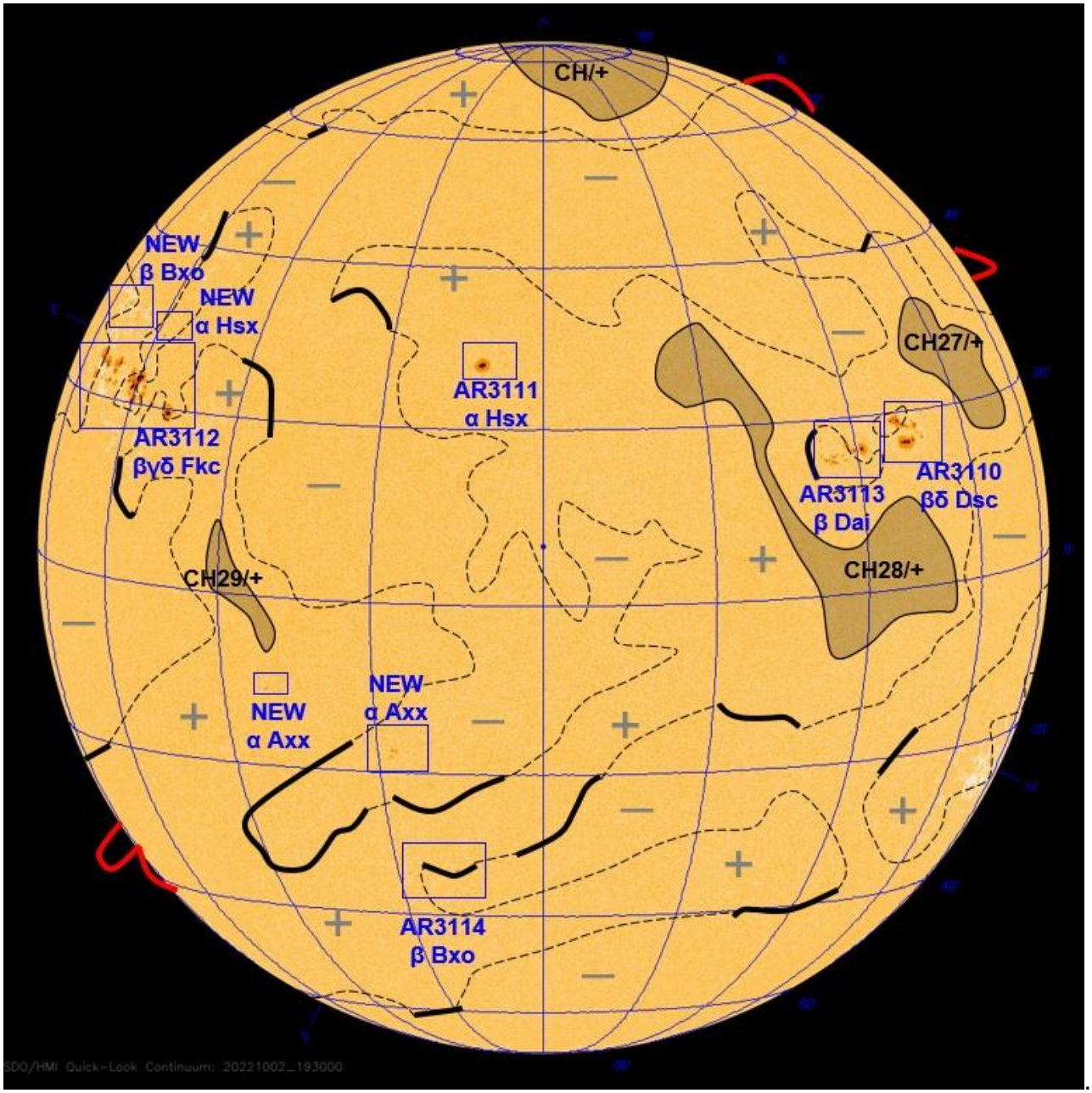
Figure 1b. Solar Analysis Valid 02/2000 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

Four CMEs have erupted from the northwest quadrant in the past 24 hours, with the potential for Earth-directed ejecta, although uncertainty remains high. The most likely to impact originated from a filament eruption to the east of AR3113 at 01/1200 UTC. Two further CMEs from AR3110 associated the M5.8 and M8.3 flares at 01/2010 and 02/0220 UTC are mainly directed away from Earth, however these have a chance to give glancing impacts. A further CME from the X1.0 of AR3110 at 02/2025 UTC has yet to be analysed.

The first CME is the most likely to provide impacts at Earth, arriving either late on day 1 (3rd) or early day 2 (4th). This is slightly earlier than previous forecast due to a slight adjustment to the previous analysis, and also the earlier arrival of the fast wind of CH28, suggesting faster background winds. Confidence remains low on the strength of any impact. The following CMEs are likely to only give glancing impacts at most, although perhaps re-enhancing conditions through day 2 and into day 3 (4th to 5th) after the initial arrival, although this is also very low confidence.

Earth has seen the fast wind of CH28 arrive, with elevated solar winds expected to persist day 1 (3rd) and into day 2 (4th), before gradually easing back towards background thereafter, once any CME influence subsides. Peak winds are likely to be around 550-600km/s on day 1 (3rd), before declining to slightly elevated levels by day 4 (6th). This gradual decline is supported by both 27-day persistence and also enlil.

Geomagnetic activity is forecast to be mainly Unsettled to Active day 1 (3rd) with G1-G2 Minor to Moderate Storms likely at first, and then a further chance of G1-G2 (Minor to Moderate storms) either late day 1 or early day 2 (3rd-4th) with any CME arrival. Ongoing CME effects would then follow on day 2 and into day 3 (4th-5th) if this arrival occurs, although there is significant uncertainty. Otherwise, a general trend back towards Quiet, with isolated Unsettled intervals is expected later day 3 and day 4 (5th-6th).

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	60	50	20	5
Strong	G3	No	15	15	1	1
Severe	G4	No	2	2	1	1
Extreme	G5	No	1	1	1	1

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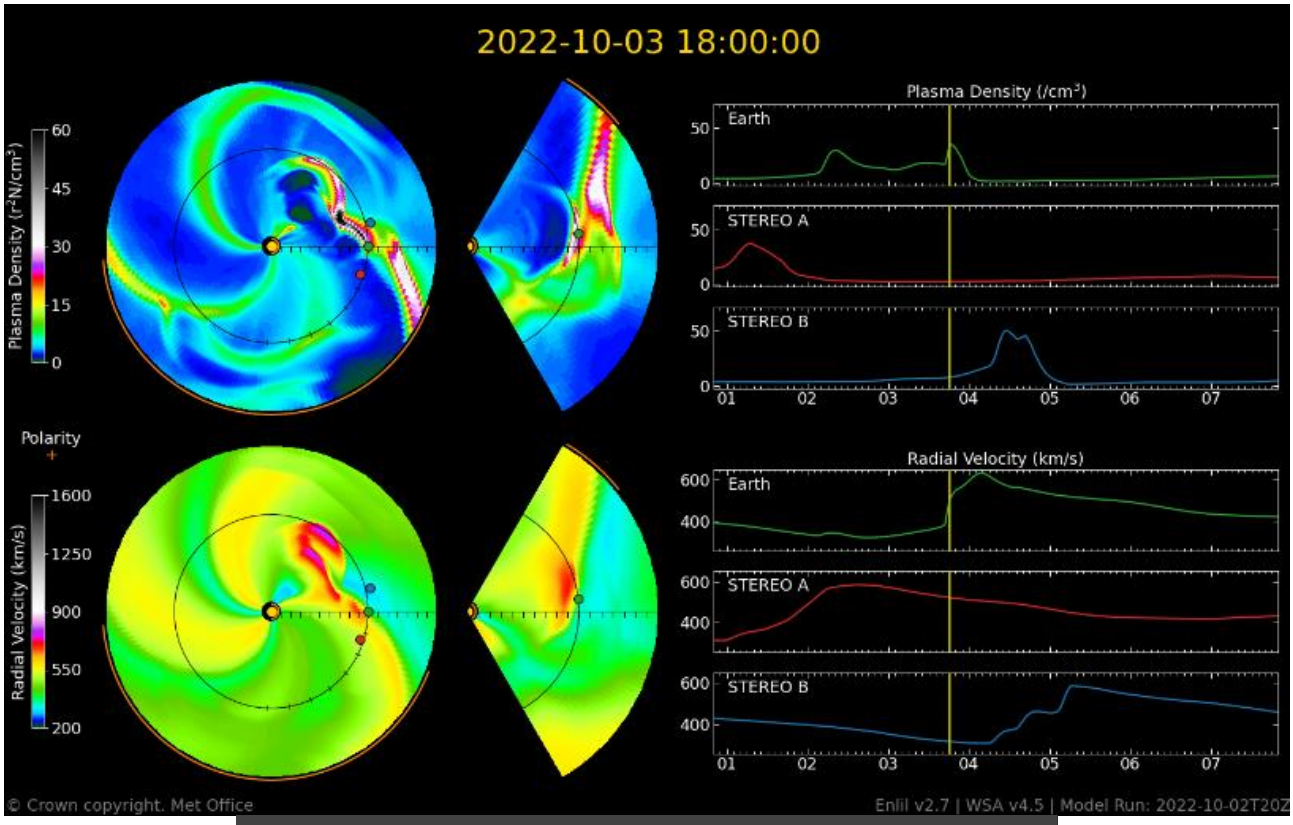
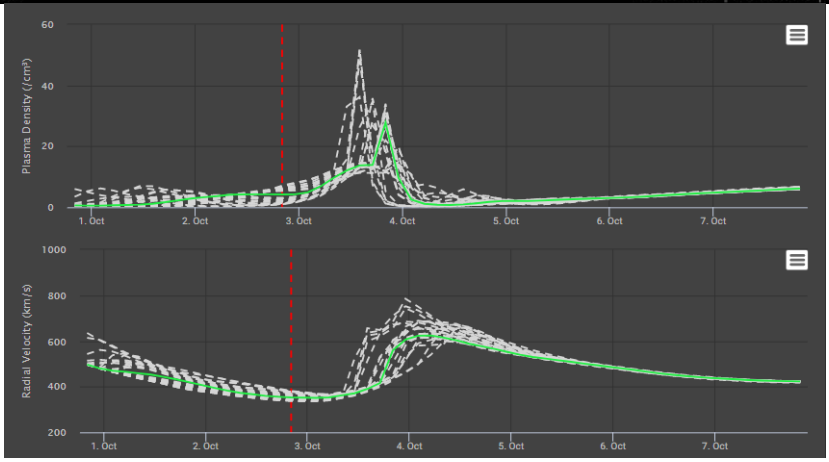
Geomagnetic Activity - Earthbound Coronal Mass Ejections

Name	Liftoff Time	Long	Lat	Radial Speed (km/s)	Half Angle	Time at 21.5Rs
CME-202210-003	2022-10-02 02:23	38W	15N	900	25	2022-10-02 06:20
CME-202210-002	2022-10-01 20:10	43W	12N	1130	26	2022-10-01 22:57
CME-202210-001	2022-10-01 12:00	38W	4N	1000	37	2022-10-01 16:25
CME-202209-032	2022-09-30 13:30	51W	3N	730	12	2022-09-30 18:35

Figure 2: Enlil and Ensemble (Showing arrival late on 3rd – Previous assessments were more on the 4th)





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Radio Blackouts - X-Ray Flares:

There are five numbered region on the Earth-facing disc, and a further three small, unnumbered but developing regions. Activity has been Strong with an AR3110 Dsc/Beta-Delta the source of an X1.0 at 02/2025 UTC and a number of M-flares. This is a relatively small but unstable region in the northwest disc due to the development of negative polarity spots to the north of a main positive polarity leader. Its penumbral extent has continued to expand since the recent X1 flare, suggesting further activity is possible. This region is likely destabilised further by nearby AR3113 Dai/Beta to the east, which a magnetic connection likely between the two regions.

AR3112 Fkc/Beta-gamma-delta in the northeast is also of notable interest, due to its large longitudinal length and recent low level M-flaring. This region consists of a long string of spots, with development still ongoing, particularly around a larger, more compact intermediate region. While not as compact or complex as the top-level Fkc region, this still has the potential for M, and perhaps X-flares.

Along with the other, less notable regions, these give a chance of further X-flares through the period, with M-flares also likely each day and activity is expected to remain Moderate to Strong.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	75	75	70	70
Very Active	R3 to R5 X Class	Yes	25	25	20	20

Figure 3a: GOES-16/17 X-ray Flux

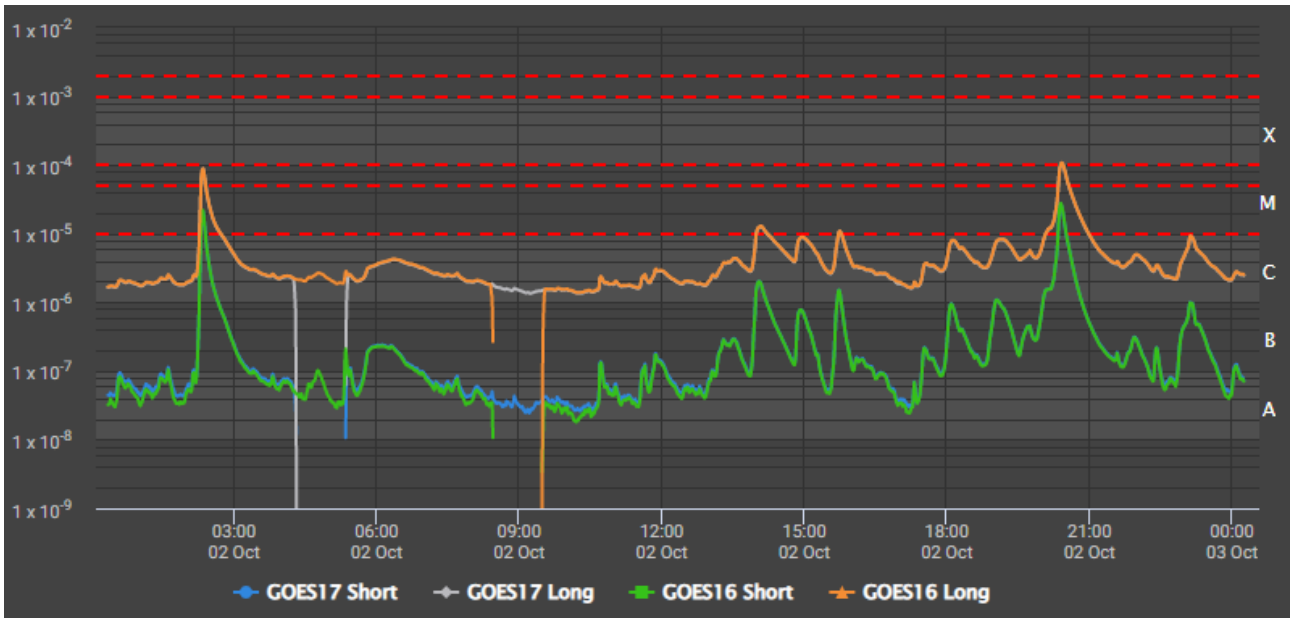

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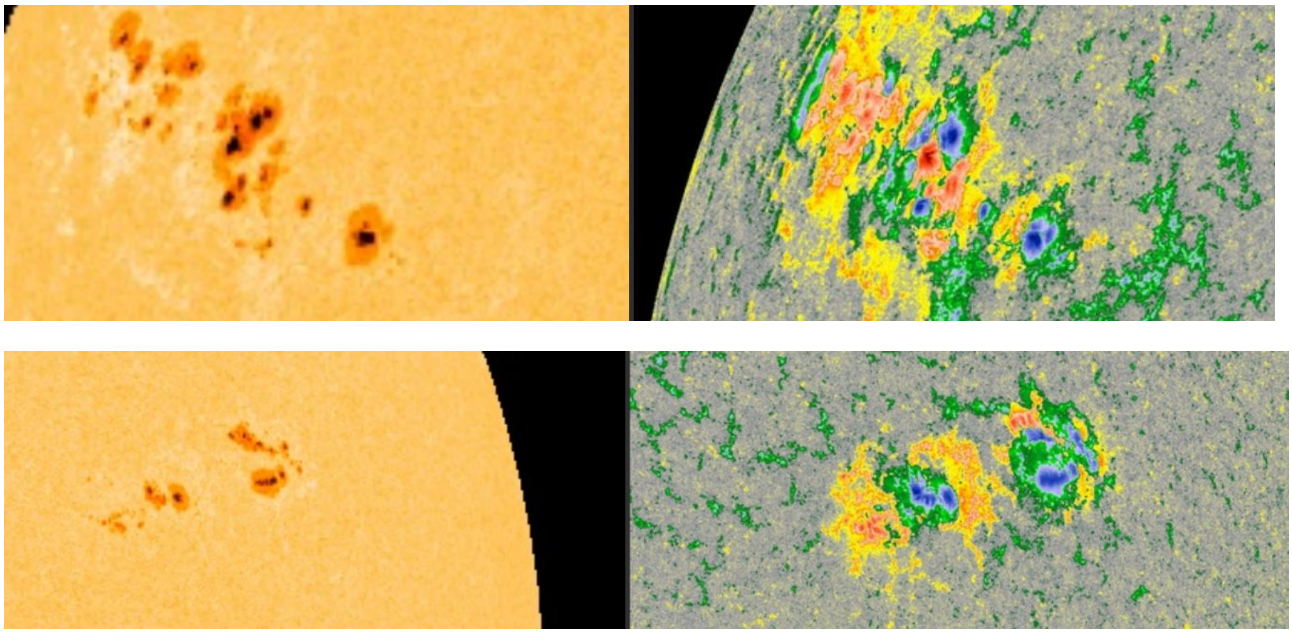
Figure 3b: SDO Intensitygram and Magnetogram of AR3112 and AR3113/AR3110 respectively

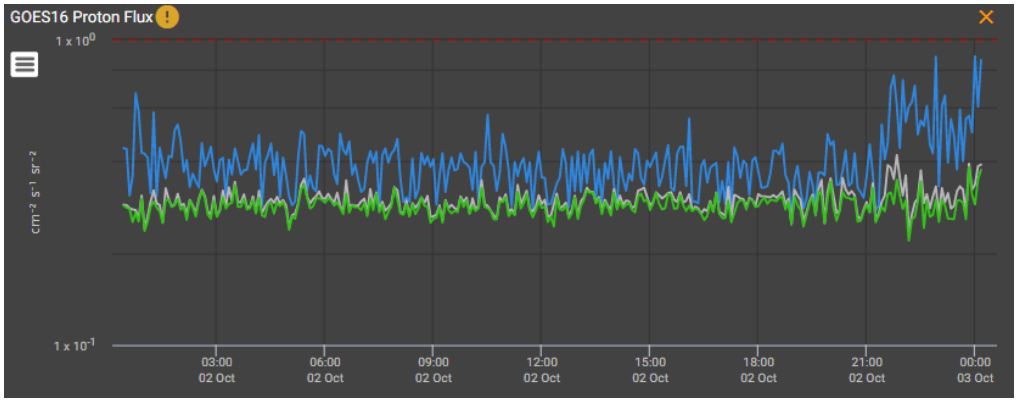


Solar Radiation Storms - (High Energy Protons):

The high energy proton flux (greater than 10MeV) as observed by GOES16 rose slightly above background due to the X-flare of AR3110 on the 2nd, but well below the S1-level. Further such rises are expected with a slight chance of exceeding this threshold, primarily from any further M or X-flares from AR3110, but potentially also from AR3112 in the northeast given a sufficiently strong flare event.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	20	20	15	15
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: GOES-16 Proton Flux



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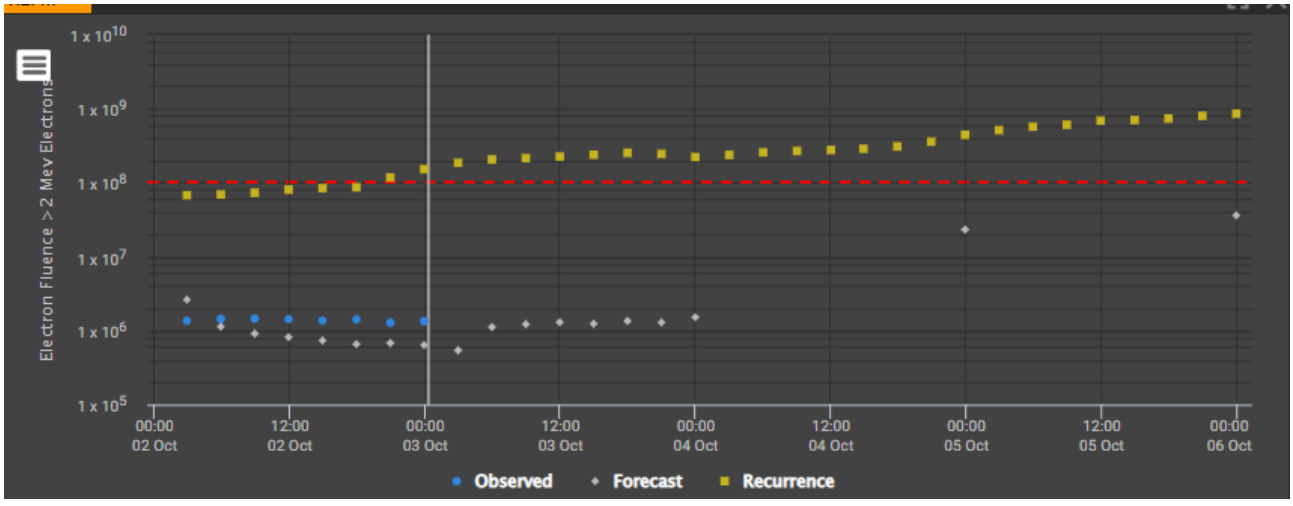
High Energy Electrons Event (≥ 2MeV):

The high energy (greater than 2MeV) electron flux has been at background levels. A rise in electron flux is expected due to the recent arrival of the fast wind CH28, however this will be complicated by the potential CME arrivals later day 1 or day 2 (3rd-4th), which would then suppress electron levels. Once any CME influence subsides, or if the arrivals are weak, then flux levels are expected to become increasingly High, from day 2 (4th), but particularly day 3 (5th) onward. If no CME arrival occurs, increasingly prolonged periods of high flux is possible from later day 1 (3rd) onward

The associated electron 24 hour fluence is likely to remain below the Active (1e8 integrated pfu) threshold, but with a rising trend and with some significant uncertainty due to the potential CME glances. Should these miss, there is the potential for electron flux to rise to Active early in the period, but most likely rising above this level as solar winds ease through days 3 and 4 (5th and 6th). REFM is currently giving good guidance for an upwards trend, but only in the absence of any CME arrival.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	10	20	40	60
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	5

Figure 5: GOES 16 >2MeV Electron Flux with REFM and Recurrence



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